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## ORIGINAL ARTICLE

# Is it worth fixing proximal humeral fractures at increased vascular risk?☆

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## KEYWORDS

Humeral fracture;  
Nailing;  
Osteonecrosis;  
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## Summary

**Objective:** To evaluate fixation of proximal humeral fractures by antegrade nailing, in terms of fracture reduction, bone healing; osteonecrosis; functional consequences of osteonecrosis and malunion.

**Design:** Prospective, consecutive, multicenter based.

**Setting:** Academic Trauma Centers; approval was received from the ethics committee of the institutions involved in the study.

**Methods:** Fifty-one patients were enrolled prospectively, with 31 3-part and 20 4-part displaced fractures (head displacement greater than 45°, tuberosity-head gap greater than 10 mm, diaphyseal gap greater than 10 mm). A Telegraph™ nail (FH Orthopedics, Heimsbrunn, France) was the fixation device used, introduced through a superolateral transdeltoid approach under fluoroscopic guidance. The assessment included Simple Shoulder Test, absolute Constant score, X-rays every 3 months and CT-scan at final evaluation. Twelve patients died and one was lost to follow-up. Immediate complications included secondary displacement in four patients.

**Results:** There were no infections, no deltoid muscle or axillary nerve damage, and all the fractures united. After a mean follow-up of 24.1 months, malunion was observed in 29% of the remaining 38 patients and osteonecrosis in 32%. Both complications were more frequent and extensive in patients with 4-part fractures. The osteonecrosis area influenced the Constant score, which was 55.8 points when the area was less than 30%, 50.6 points between 30 and 50%, and 38 points when larger than 50%. Head malunion affected the Simple Shoulder Test and the Constant score.

☆ Study promoted by Rennes University Hospital (2002).

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*Conclusion:* Nailing may thus be recommended for 3-part fractures, because osteonecrosis is less frequent, more focused, and better tolerated in this sub-group. In contrast, antegrade nailing was not more beneficial than other internal fixation techniques for preventing osteonecrosis or head malunion in patients with 4-part fractures.

*Level of evidence:* Level IV: prospective study.

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## Introduction

Surgery is indicated for fractures of the proximal humerus in case of joint instability or marked displacement of the fracture segments. The choice between internal fixation and arthroplasty is still debated and depends on bone quality and the risk of head osteonecrosis (ON) [1,2]. The latter appears in case of dislocation, but is also related to the type of fracture, which may disrupt intracapsular or intraosseous vessels [2–4]. The risk of ON appears to be lower with stable impacted 4-part fractures in valgus [5–7] or with 3-part fractures even if ON has been described in case of large or markedly displaced tuberosity fragment [8] (Fig. 1). Anterograde nailing with cephalic screw fixation through a superior approach has been reported as an option to reduce soft-tissue insult during open reduction and fixation in order to lower the risk of ON and avoid articular replacement [9–11]. This study was designed to prospectively evaluate this technique used for 3- and 4-part displaced fractures, and aimed to evaluate: bone union and fracture reduction; osteonecrosis; and functional consequences of malunion and ON.

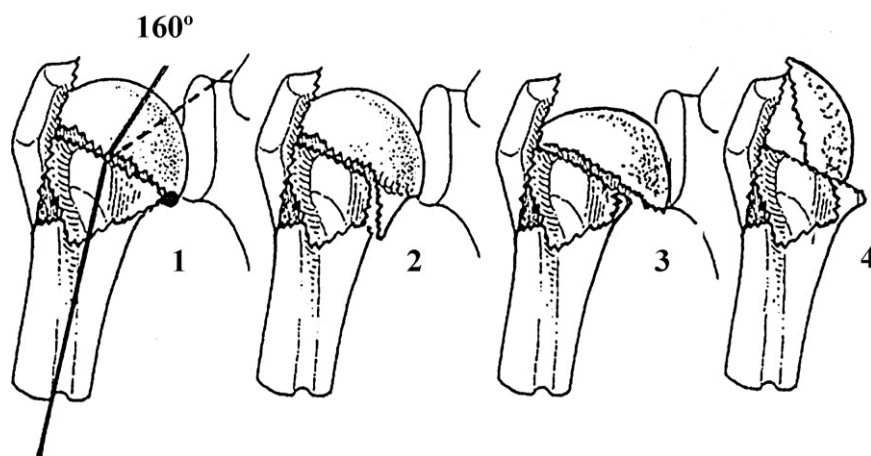
## Patients and methods

Two hundred and thirty-three patients were treated for fractures of the proximal humerus in the emergency departments of three academic hospitals between 1st January

2003 and 30 June 2004. Approval was received from the ethics committee of the institutions involved in the study. Patients were questioned preoperatively on the prefracture function of their involved shoulder by means of the Shoulder Simple Test (SST) [12]. Standard radiography (anteroposterior and lateral scapular views), followed by computed tomography scanner (CT-scan) were used to classify the fractures according to Neer [8]. The indications for surgery were based on anatomical criteria, i.e. head displacement greater than 45°, tuberosity-head gap greater than 10 mm, diaphyseal gap greater than 10 mm, and the patient's general health [8]. When the humeral head was displaced, its coronal angulation was measured relative to the neutral angle of 145° (varus less than 145°, valgus greater than 145°), and the presence of a medial hinge and head extension was noted [4] (Fig. 2). Nailing was used systematically for eligible patients, and arthroplasty was not used during the inclusion period for such patients. Patients were excluded if they had 2-part fractures, undisplaced 3- and 4-part fractures, joint dislocation, surgical contraindications related to their general or mental health, or if they refused the operation. Nailing was performed with the patient seated, using a superolateral transdeltoid approach with fluoroscopic guidance and using the first model (unlocked screw) of the Telegraph™ Nail (FH Orthopedics, Heimsbrunn, France). For 3-part fractures the nail was introduced through the rotator cuff between the top of the head and the anatomical neck, then the fractured tuberosities were



**Figure 1** 3-part fracture with greater tuberosity detachment. This type may also be associated with vascular impairment and a risk of osteonecrosis (5).

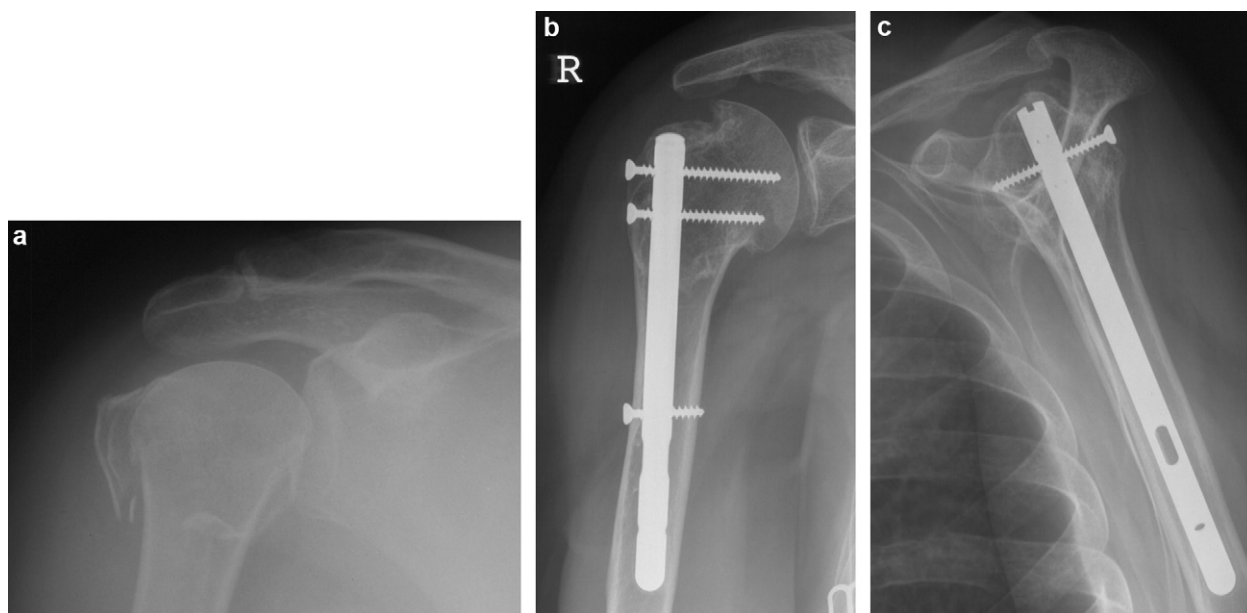


**Figure 2** Different types of displaced 4-part fractures: case 1 is a 4-part fracture “impacted-valgus” (dotted line: neutral angle of  $145^\circ$ ) with an intact medial hinge (black spot), case 2 has a head extension, while cases 3 (valgus) and 4 (varus) show disruption of the medial hinge.

fixed by frontal or sagittal screwing. For 4-part fractures the nail was introduced between the fractured tuberosities. After reduction, the proximal end of the nail acted as a buttress to support the head. Simultaneous fixation of the head and of the greater tuberosity were achieved with two coronal screws through the proximal end of the nail. Lesser tuberosity were either fixed by one anteroposterior screw or sutured to the greater tuberosity. The rotational and longitudinal stability of the nail was always ensured by percutaneous distal locking at the level of the deltoid tendon (Fig. 3b,c). Patients were immobilized with a splint for a minimum period of 3 weeks during which only passive mobilization was undertaken by a physiotherapist.

Postoperatively, the study design included SST, absolute Constant score [13], X-rays (AP and lateral scapular views)

every 3 months, and a CT scan was obtained at 18 months of follow-up. Bone union was defined by evidence of a callus between the fracture segments on X-ray or CT-scan examination. Fracture reduction was considered either anatomical or malunited when head angulation exceeded  $20^\circ$  (coronal or sagittal), and tuberosity displacement 5 mm. Osteonecrosis was quantified by CT-scan as the percentage of the affected area of the humeral head on axial-transverse images ( $< 30\%$ ,  $30\text{--}50\%$  or  $> 50\%$ ) and graded with the Cruess classification: grade 2 in the presence of a hypodense geodic or biconvex lens image with a well-preserved shape, grades 3 and 4 in case of subchondral bone collapse with loss of head sphericity (extensive in grade 4) [14] (Fig. 4). Radiological analysis had to obtain the agreement of the three observers (HT, GK, JR). Qualitative data are reported as numbers and



**Figure 3** Pre- (left) and postoperative (right) views of a 4-part impacted valgus treated with a Telegraph™ nail. Note the position of the three proximal screws (two coronal and one sagittal).



**Figure 4** Four-part valgus fracture, with good initial reduction of the head and tuberosities. The absolute Constant score was 81 points at 1 year but dropped to 42 points at 2 years. ON corresponded to Cruess grade 4 (note that the medial hinge was preserved but that there was no head extension).

**Table 1** Fracture types of the 233 patients in the cohort (one year inclusion, three centers).

Fracture types	Patients in the cohort <i>n</i> = 233 (%)	Patients included <sup>a</sup> <i>n</i> = 51 (%)
Fracture from Hill-Sachs notch	1 (0.4)	
2-part lesser tuberosity	1 (0.4)	
2-part greater tuberosity	29 (12.4)	
2-part surgical neck	58 (24.9)	
3-part tuberosity	69 (29.6)	31 (61)
4-part	75 (32.2)	20 (39)

<sup>a</sup> 59 met the inclusion criteria (undisplaced fracture and fracture-dislocation had been excluded), and 51 had been included for internal fixation (no arthroplasty had been performed during the inclusion period)..

percentages, and quantitative data as the mean, median, standard deviation and range. Relations between two qualitative variables were tested with the Chi<sup>2</sup> test or Fisher's exact test, and means were compared with the Mann-Whitney non-parametric test. Wilcoxon's non-parametric test was used to compare values between two times points. Significance was assumed at  $P < 0.05$ . SPSS 13.0 statistical software (SPSS Inc., Chicago Illinois, USA) was used for all analyses.

## Results

Among the 233 patients, 59 met the inclusion criteria for this study (Table 1). Eight of these patients did not have surgery, because of their general health or because they refused it. The remaining 51 patients had nailing. Mean age was 69.2 years (73.8, 15.8, 18–95) and the female/male sex ratio was 1.7. The mean pre-fracture SST score was 9.8/12 (11, 2.8, 1–12). There were 31 3-part fractures and 20 4-part fractures. In patients with 4-part fractures, a medial hinge was present in 11 cases and there were seven head extensions, with a mean length of 5.9 mm (6, 1.8, 4–9). The patients

were operated on a mean of 2.5 days (1, 2.5, 0–10) after the fracture. Two coronal proximal screws were used in 49 cases, one in two cases and sagittal screws were used in 12 cases. The arm was immobilized for an average of 3.9 weeks (3, 2.7, 3–21).

At time of final reassessment, 12 patients had died of unrelated causes and one patient had been lost to follow-up. The other 38 patients were reexamined an average of 24.1 months (21, 5.1, 16–34) after the operation (21 3-part and 17 4-part fractures: 13 with a valgus impacted head and four in varus). The mean SST was 7.6 points (8, 3.5, 0–12), i.e. 2.6 points lower than before the trauma ( $P = 0.001$ ). The mean absolute Constant score was 55.6 points (54, 19, 21–100); using the detailed Constant score system, the mean final pain score was 11.3/15 points (10, 3.4, 0–15), the overall activity score 13.8/20 points (14, 4.3, 5–20), and the painless active mobility score 23.4/40 points (22, 9.8, 10–40). Anterior active flexion was 113° (100, 36, 45–180) and active external rotation was 5.6/10 points (5, 3.7, 0–10).

There were no infection, deltoid muscle or axillary nerve damage. All 38 patients had standard radiographies, and 95% had CT-scan. There was no case of head or tuberosity non-union. Immediate postoperative complications included secondary displacement in four patients, all with 3-part fractures for which the screws did not prevent secondary angulation of the head. Eleven patients (29%) had head malunion, five out of 21 3-part (all varus) and six out of 17 four part fractures (three varus and three valgus). In those latter cases it was always linked to poor initial reduction (three out of four in varus and three out of 13 valgus impacted). Seven patients (18%) had malunion of the tuberosities.

Twelve patients (32%) had ON, which was more extensive in patients with 4-part fractures (Table 2). In 4-part fractures the preoperative head angulation did not influence the occurrence of ON (six out of 13 valgus and two out of four varus). In these fractures, ON tended to be less frequent when the medial hinge was intact, but the difference was not statistically significant. Among the seven cases with a radiologic head extension, two measured more than 6 mm and showed no ON, while five measured less than 6 mm and three of these showed ON.

**Table 2** Patients with osteonecrosis or malunion at 24.1 months mean follow-up (*n* = 38).

	3-part tuberosity <i>n</i> = 21	4-part <i>n</i> = 17	<i>P</i> value
<i>Osteonecrosis</i>	4	8	0.06
< 30%	4	1	Not tested
30–50%	0	2	
> 50% and/or head collapsed	0	5	
<i>Head malunion (&gt; 20°)</i>	5	6	ns
<i>Tuberosity malunion (&gt; 5 mm)</i>	3	4	ns

ns: statistically not significant.



**Table 3** Links between anatomical and functional results (SST: Simple Shoulder Test) ( $n = 38$ ).

	Osteonecrosis ( $n = 12$ )	No osteonecrosis ( $n = 26$ )	<i>P</i> value	Cephalic malunion ( $n = 13$ )	No cephalic malunion ( $n = 25$ )	<i>P</i> value
SST	6.6	8.3	ns	5.9	8.7	0.02
Constant	45.3	61.6	0.02	45.2	62.4	0.01
Flexion	92°	123.5°	0.01	95°	123.3°	0.02
Pain	10.4	11.6	ns	11.3	11.2	ns

ns: statistically not significant.

ON influenced the Constant score and active flexion. Head malunion affected the SST, the Constant score, and active flexion (Table 3). The Constant score decreased with the area of ON, from 55.8 points (63, 21.1, 21–77) when necrosis was less than 30%, to 50.6 points (54, 19.7, 21–77) between 30% and 50%, and 38 points (34, 14.4, 26–63) above 50%. Active flexion was 123.5° (115, 35, 70–180) in the absence of ON, 106.4° (95, 21, 80–150) with ON < 50%, and 66.3° (70, 15, 45–80) with ON > 50%. Seven patients had both ON and head malunion (all greater than 20°) and their Constant score was 40.

## Discussion

The mortality rate was high (23.5% at 24 months) and represents a limitation of the study. It is probably due to its prospective design and to the average age at enrollment (69.2 years). Zyto et al., in a prospective study of 40 patients (mean age of 74 years) with 3- or 4-part fractures, observed a mortality rate of 20% at 4.2 years of follow-up [15,16]. The mean age of our patients was therefore higher than in series focusing on internal fixation, in which bone quality was an inclusion criterion [4,6,17–20], but close to that in hemiarthroplasty studies [21] and epidemiological studies [22]. This may confirm that proximal humeral fracture is an independent predictor of mortality, in both sexes in the short term and especially in men in the mid term [23,24].

This series reports a high rate (29%) of head malunion, which affected the functional results. Koike et al., using the Polarus nail, reported 16% of “residual deformities”, mainly in varus (50%), but this series included a majority of 2- and 3-part fractures (93%) [11]. Contrary to other series [9,17], most of the malunions in the present series were linked to suboptimal initial reduction and not to screw failure. The upper approach no doubt favors reduction of the tuberosities, but perhaps not of the head, despite the use of fluoroscopy. Among the 13 fractures in valgus, three still had a head defect of 20° after the operation, a rate close to that reported by Resch et al. (27%), while Gerber et al. avoided such malunions by using a supportive graft [20,25]. Finally, only four secondary displacements were observed (10%), a rate lower than in other nailing series [9]. Locking of the screws may represent an improvement [26] but bone quality will probably remain the main limitation [1,20,27].

This study was mainly designed to determine the rate of ON after systematic nailing of fractures with a high vascular risk (3-part fractures with tuberosity displacement and 4-part fractures). The rate of 32% of ON is in contrast with

that of other series with surgical fixation [10,26,28–30]. This rate varies widely in literature. Major reasons include retrospective enrollment and survey, poor description of fracture types and their displacements, mixing of fractures with high and low vascular risks (i.e. 2- and 3-part without tuberosity detachment), and insufficient follow-up (less than 2 years). Robinson and Page reported no cases of ON after repairing 25 impacted fractures in valgus with wide coronal angulation (mean 171°, 162–205°), but only 12 of their 25 patients had imaging studies at two years [7]. In a prospective study Gradl et al. reported a 5% rate of ON in a group of 76 Targon™ nailing procedures but 72% of the enrolled patients had 2- and 3-part fractures and the mean follow-up was only 1 year [29]. In fact, the rate of ON is usually above 20% when radiological studies are done at least two years after surgery (Table 4). The present series shows that the type of fracture influences the frequency and severity of ON, in agreement with Resch et al. [25] and Schai et al. [18]. In 3-part fractures, ON is always fragmentary and below 30%, and does not progress to cephalic collapse. In contrast, 4-part fractures carry a risk of severe ON. The presence of a medial hinge and anterior head extension were both associated with better outcome. Contrary to other authors [7,17,25,31], we did not find that head displacement in valgus rather than in varus was associated with better outcome. All these fractures correspond to the type 12 of Hertel et al., who found persistent arterial flow intraoperatively in only 26% of such cases [4]. Intracapsular vascularization is therefore strongly compromised, and revascularization by “creeping substitution”, advocated by other authors [17,32,33], is probably rare and unpredictable.

In this series ON strongly impaired functional results. Osteonecrosis below 50%, and especially below 30% of humeral head is often referred to as “partial” in the literature (Cruess 2), and is well tolerated, while head collapse greater than 50%, often referred to as “complete” or “total” (Cruess 3 and 4), is associated with major functional consequences [3,6,17,18]. In summary, 19% of 3-part fractures showed partial, well-tolerated ON, supporting the use of fixation for this fracture type [17]. In contrast, ON occurred in 47% (8/17) of non-dislocated 4-part fractures and was usually massive or collapsed (Fig. 4).

When considering internal fixation of 4-part fractures, surgeons must be aware of the rate of potential complications. The present series demonstrates that antero-grade nailing doesn't prevent ON which is poorly tolerated. Further prospective studies must be conducted comparing nailing and plating with a randomized design. Intraoperative reduction of the head represents a key-point for the future of those conservative techniques.

**Table 4** Rate of osteonecrosis after fixation of proximal humeral fractures.

	<i>n</i>	Follow-up (years)	Types of the fractures	% osteonecrosis	% "total" osteonecrosis
Sturzenegger et al. (1982) [30]	27	3.5	3 and 4-part	22.2	—
Jakob et al. (1991) [6]	19	4.2	4-part impacted valgus	26	26
Jaberg et al. (1992) [32]	48	3	Unstable: 2, 3, 4-part	21	4
Schai et al. (1997) [18]	61	4.1	3 and 4-part	42	16
Resch et al. (1997) [25]	27	2	3 and 4-part	11	—
Duparc and Hutten (1998) [2]	122	4.2	4-part	42	26
Cuny et al. (2003) [17]	23	2	4-part	9	—
Robinson and Page (2003) [7]	25	1–2	4-part impacted valgus	0	—
Gerber et al. (2004) [20]	34	5.2	2, 3, 4-part	35	14.7
Bigorre et al. (2009) [28]	93	1.5	3 and 4-part	7.5	—
Present series	38	2	3 and 4-part	32	13

## Conclusion

Systematic fixation of 3- and 4-part humeral proximal fractures allows bone union but does not prevent osteonecrosis, which was observed in one-third of cases. Osteonecrosis and head malunion significantly degrade the functional results. This study supports the conclusion that fixation may be recommended for 3-part fractures, because osteonecrosis is less frequent, more partial, and well tolerated. In contrast, fixation by nailing, even when performed with a mildly aggressive upper approach, was not more beneficial than other internal fixation techniques for the treatment of 4-part fractures, with respect to osteonecrosis or head malunion.

## Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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